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IN THE MATTER OF

U.S. Patent Application No. 09/609,822

By Samsung Electronics Co., Ltd.

I, Soon-hee Lee, an employee of Y.P.LEE,MOCK & PARTNERS of The Cheonghwa Bldg., 1571-18 Seocho-dong, Seocho-gu, Seoul, Republic of Korea, hereby declare that I am familiar with the Korean and English languages and that I am the translator of the priority document (Korean Patent Application No. 1998-29732) and certify that the following is to the best of my knowledge and belief a true and correct translation.

Signed this 14th day of September 2004.

Soon hee Lee

ABSTRACT

[Abstract of the Disclosure]

An adaptive writing method for a high-density optical recording apparatus and a circuit thereof are provided. The circuit includes a discriminator for discriminating the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces, a generator for controlling the waveform of the write pulse in accordance with the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces to generate an adaptive write pulse, and a driver for driving the light source by converting the adaptive write pulse into a current signal in accordance with driving power levels for the respective channels. The widths of the first and/or last pulses of a write pulse waveform are varied in accordance with the magnitude of the present mark of input NRZI data and the magnitude of the leading and/or trailing spaces, thereby minimizing jitter to enhance system reliability and performance.

[Representative Drawing]

FIG. 2

SPECIFICATION

[Title of the Invention]

Adaptive Writing Method for High-Density Optical Recording Apparatus and Circuit Thereof

[Brief Description of the Drawings]

FIGS. 1A through 1E are waveform diagrams of conventional write pulses;

FIG. 2 is a block diagram of an adaptive writing circuit for a high-density optical recording apparatus according to an embodiment of the present invention;

FIGS. 3A through 3G are waveform diagrams of an adaptive write pulse recorded by the adaptive writing circuit shown in FIG. 2;

FIG. 4 illustrates grouping of input data;

FIG. 5 is a table illustrating the combination of pulses generated by the grouping shown in FIG. 4;

FIG. 6 is a table illustrating rising edge shift values of a first pulse according to the present invention;

FIG. 7 is a table illustrating falling edge shift values of a last pulse according to the present invention;

FIG. 8 is a flowchart of an adaptive writing method according to an embodiment of the present invention; and

FIG. 9 is a graph for comparing jitter generated by the adaptive writing method of the present invention and the conventional writing method.

[Detailed Description of the Invention]

[Object of the Invention]

[Technical Field of the Invention and Related Art prior to the Invention]

The present invention relates to an adaptive writing method for a high-density optical recording apparatus and a circuit thereof, and more particularly, to an adaptive writing method for optimizing light power of a light source, e.g., a laser diode, to be

suitable to characteristics of a recording apparatus, and a circuit thereof.

With the multi-media era requiring high-capacity recording media, optical recording systems employing high-capacity recording media, such as a magnetic optical disc drive (MODD) or a digital versatile disc random access memory (DVD-RAM) drive, have been widely used.

As the recoding density increases, such optical recording systems require optimal and high-precision states. In general, with an increase in recording density, temporal fluctuation (to be referred to as jitter, hereinafter) in a data domain increases. Thus, in order to attain high-density recording, it is very important to minimize the jitter.

Conventionally, a write pulse is formed as specified in the DVD-RAM format book shown in FIG. 1B, with respect to input NRZI (Non-Return to Zero Inversion) data having marks of 3T, 5T and 11T (T being the channel clock duration), as shown in FIG. 1A. Here, the NRZI data is divided into mark and space. The spaces are in an erase power level for overwriting. The waveform of a write pulse for marks equal to or longer than 3T mark, that is, 3T, 4T,...11T and 14T is comprised of a first pulse, a last pulse and a multi-pulse train. Here, only the number of pulses in the multi-pulse train is varied depending on the magnitude of a mark.

In other words, the waveform of the write pulse is comprised of a combination of read power (FIG. 1C), peak power or write power (FIG. 1D) and bias power or erase power (FIG. 1E). Here, the respective power signals shown in FIGS. 1C, 1D and 1E are all low-active signals.

The waveform of the write pulse is the same as that in accordance with the first generation 2.6 GB DVD-RAM standard. In other words, in accordance with the 2.6 GB DVD-RAM standard, the waveform of the write pulse is comprised of a first pulse, a multi-pulse train and a last pulse. Although the rising edge of the first pulse or the falling edge of the last pulse can be read from a lead-in area to be used, adaptive writing is not possible since the write pulse is fixed to be constant.

Therefore, when a write operation is performed by forming such a write pulse as shown in FIG. 1B, severe thermal interference may occur back and forth with respect to

a mark in accordance with input NRZI data. In other words, when a mark is long and a space is short or vice versa, jitter is most severe. This is a major cause of lowered system performance. Also, this does not make it possible for the system to be applied to high-density DVD-RAMs, e.g., second generation 4.7 GB DVD-RAMs.

[Technical Goal of the Invention]

To solve the above problems, it is an objective of the present invention to provide an adaptive writing method of a write pulse generated in accordance with the magnitude of the present mark of input data and the magnitudes of the leading and/or trailing spaces thereof.

It is another objective of the present invention to provide an adaptive writing circuit for a high-density optical recording apparatus for optimizing light power of a laser diode by generating an adaptive write pulse in accordance with the magnitude of the present mark of input data and the magnitudes of the leading and trailing spaces thereof.

Accordingly, to achieve the first objective, there is provided a method for writing input data on an optical recording medium by a write pulse whose waveform is comprised of a first pulse, a last pulse and a multi-pulse train, the adaptive writing method including the steps of controlling the waveform of the write pulse in accordance with the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces to generate an adaptive write pulse, and writing the input data by the adaptive write pulse on the optical recording medium.

To achieve the second objective, there is provided an apparatus for writing input data on an optical recording medium by a write pulse whose waveform is comprised of a first pulse, a last pulse and a multi-pulse train, the adaptive writing circuit including a discriminator for discriminating the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces, a generator for controlling the waveform of the write pulse in accordance with the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces to generate an

adaptive write pulse, and a driver for driving the light source by converting the adaptive write pulse into a current signal in accordance with driving power levels for the respective channels.

[Structure and Operation of the Invention]

Hereinafter, a preferred embodiment of an adaptive writing method for a high-density optical recording apparatus and a circuit thereof will be described with reference to the accompanying drawings.

An adaptive writing circuit according to the present invention, as shown in FIG. 2, includes a data discriminator 102, a write waveform controller 104, a microcomputer 106, a write pulse generator 108 and a current driver 110. In other words, the data discriminator 102 discriminates input NRZI data. The write waveform controller 104 corrects the waveform of a write pulse in accordance with the discrimination result of the data discriminator 102 and land/groove signal. The microcomputer 106 initializes the write waveform controller 104 or controls the data stored in the write waveform controller 104 to be updated in accordance with write conditions. The write pulse generator 108 generates an adaptive write pulse in accordance with the output of the write waveform controller 104. The current driver 110 converts the adaptive write pulse generated from the write pulse generator 108 into a current signal in accordance with the light power levels of the respective channels to drive a light source.

Next, the operation of the apparatus shown in FIG. 2 will be described with reference to FIGS. 3 through 7.

In FIG. 2, the data discriminator 102 discriminates the magnitude of a mark corresponding to the present write pulse (to be referred to as a present mark), the magnitude of the front-part space corresponding to the first pulse of the present mark (to be referred to as a leading space, hereinafter) and the magnitude of the rear-part space corresponding to the last pulse of the present mark (to be referred to as a trailing space) from input NRZI data, and applies the magnitudes of the leading and trailing spaces and the magnitude of the present mark to the write waveform controller 104.

Here, the magnitudes of the leading and trailing spaces and the magnitude of the present mark may range from 3T to 14T. There can be more than 1,000 possible combinations. Thus, circuits or memories for obtaining the amounts of shift in rising edges of the first pulses and falling edges of the last pulses are necessary with respect to all cases, which complicates the system and hardware. Therefore, in the present invention, the magnitudes of the present mark and the leading and trailing spaces of input NRZI data are grouped into a short pulse group, a middle pulse group and a long pulse group and the grouped magnitudes of the present mark and the leading and trailing spaces are used.

The write waveform controller 104 shifts the rising edge of the first pulse back and forth in accordance with the magnitudes of the leading space and the present mark, supplied from the data discriminator 102, or shifts the falling edge of the last pulse back and forth in accordance with the magnitudes of the present mark and the trailing space, to thus form a write waveform having an optimal light power. Here, the multi-pulse train of a mark takes the same shape as shown in FIG. 3B, that is, 0.5 T.

Also, the write waveform controller 104 can correct the rising edge of the first pulse of the present mark and the falling edge of the last pulse of the present mark into different values in accordance with externally applied land/groove signals (LAND/GROOVE) indicating whether the input NRZI data is in a land track or a groove track. This is for forming a write waveform in consideration of different optimal light powers depending on the land and groove. A difference of 1-2 mW in the optimal light powers between the land and the groove, and may be specifically set or managed by the specifications.

Therefore, the write waveform controller 104 may be constituted by a memory in which data corresponding to a shift value of the rising edge of the first pulse and a shift value of the falling edge of the last pulse in accordance with the magnitude of the present mark of input NRZI data and the magnitudes of the leading and trailing spaces thereof, is stored, or a logic circuit. In the case that the write waveform controller 104 is constituted by a memory, the widths of the first pulse and the last pulse are

determined as channel clocks (T) plus and minus a data value (shift value) stored in the memory. Also, in this memory, shift values of the first and last pulses of the mark for each of a land and a groove may be stored. A table in which the shift value of the rising edge of the first pulse is stored and a table in which the shift value of the falling edge of the last pulse is stored may be incorporated. Alternatively, as shown in FIGS. 6 and 7, two separate tables may be prepared.

A microcomputer 106 initializes the write waveform controller 104 or controls the shift values of the first and/or last pulse(s) to be updated in accordance with recording conditions. In particular, in accordance with zones, the light power can vary or the shift values of the first and last pulses can be reset.

The pulse width data for controlling the waveform of the write pulse is provided to the write pulse generator 108. The write pulse generator 108 generates an adaptive write pulse, as shown in FIG. 3F, in accordance with the pulse width data for controlling the waveform of the write pulse supplied from the write waveform controller 104 and supplies control signals shown in FIGS. 3C, 3D and 3E, for controlling the current flow for the respective channels (i.e., read, peak and bias channels) for the adaptive write pulse, to the current driver 110.

The current driver 110 converts the driving level of the light power of the respective channels (i.e., read, peak and bias channels) into current for a control time corresponding to the control signal for controlling the current flow of the respective channels to allow the current to flow through the laser diode so that an appropriate amount of heat is applied to the recording medium by continuous ON-OFF operations of the laser diode or a change in the amounts of light. Here, a record domain as shown in FIG. 3G is formed on the recording medium.

FIG. 3A shows input NRZI data, which is divided into mark and space. FIG. 3B shows a basic write waveform, in which the rising edge of the first pulse of the write pulse lags behind by 0.5T, compared to the rising edge of the present mark. FIG. 3C shows the waveform of a read power of the adaptive write pulse, FIG. 3D shows the waveform of a peak power of the adaptive write pulse, and FIG. 3E shows the waveform

of a bias power of the adaptive write pulse. FIG. 3F shows the waveform of the adaptive write pulse proposed in the present invention. The rising edge of the first pulse of the write waveform of the adaptive write pulse may be shifted back and forth in accordance with a combination of the magnitude of the leading space and the magnitude of the present mark. An arbitrary power (Here, a read power or a write power) is applied during the period corresponding to the shift. Likewise, the falling edge of the last pulse of the adaptive write pulse may be shifted back and forth in accordance with a combination of the magnitude of the present mark and the magnitude of the trailing space. Also, an arbitrary power (here, a read power or a write power) is applied during the period corresponding to the shift.

Alternatively, the falling edge of the last pulse may be shifted back and forth in accordance with the magnitude of the present mark, regardless of the magnitude of the trailing space of the present mark. Also, rather than shifting the rising edge of the first pulse and the falling edge of the last pulse, the edge of any one pulse may be shifted. Also, in view of the direction of shift, shifting may be performed back and forth, only forward or only backward.

FIG. 4 illustrates grouping of input NRZI data, showing two examples of grouping. In the first example, if a low grouping pointer is 3 and a high grouping pointer is 12, then the mark of a short pulse group is 3T, the marks of a middle pulse group are from 4T to 11T and the mark of a long pulse group is 14T. In the second example, if a low grouping pointer is 4 and a high grouping pointer is 11, then the marks of a short pulse group are 3T and 4T, the marks of a middle pulse group are from 5T to 10T and the marks of a long pulse group are 11T and 14T. As described above, since both the low grouping pointer and the high grouping pointer are used, utility efficiency is enhanced. Also, grouping can be performed differently for the respective zones.

FIG. 5 illustrates the number of cases depending on combinations of leading and trailing spaces and present marks, in the case of classifying input NRZI data into three groups, as shown in FIG. 4, using grouping pointers. FIG. 6 illustrates a table showing shift values of rising edges of the first pulse depending on the magnitude of the leading

space and the magnitude of the present mark. FIG. 7 illustrates a table showing shift values of falling edges of the last pulse depending on the magnitude of the present mark and the magnitude of the trailing space.

FIG. 8 is a flow chart illustrating an embodiment of an adaptive writing method of the present invention. First, a write mode is set (step S101). If the write mode is set, it is determined whether it is an adaptive writing mode or not (step S102). If it is determined in step S102 that the write mode is an adaptive write mode, a grouping pointer is set (step S103). Then, a grouping table depending on the set grouping pointer is selected (step S104). The selected grouping table may be a table reflecting land/groove as well as the grouping pointer. Also, the selected grouping table may be a table reflecting zones of the recording medium.

Shift values of the rising edge of the first pulse are read from the table shown in FIG. 7 in accordance with a combination of the present mark and the trailing space (step S106).

The adaptive write pulse in which the first pulse and the last pulse are controlled in accordance with the read shift value is generated (step S107). Then, the light powers of the respective channels for the generated adaptive write pulse, i.e., read, peak and bias powers, are controlled to drive a laser diode (step S108) to then perform a write operation on a disc (step S109). If the write mode is not an adaptive write mode, a general write pulse is generated in step S107.

FIG. 9 is a graph for comparing jitter generated by the adaptive writing method according to the present invention and the conventional writing method. It is understood that, assuming that the peak light is 9.5 mW, the bottom power of a multi-pulse train is 1.2 mW, the cooling power is 1.2 mW and the bias power is 5.2 mW, there is less jitter generated when writing the adaptive write pulse according to the present invention than when generated writing the fixed write pulse according to the conventional writing method. The initialization conditions are a speed of 4.2 m/s, an erase power of 7.2 mW and 100 write operations.

In other words, according to the present invention, in adaptively varying the marks of a write pulse, the rising edge of the first pulse is adaptively shifted in accordance with the magnitude of the leading space and the magnitude of the present mark of input NRZI data to thus control the waveform of the write pulse, and/or the falling edge of the last pulse is adaptively shifted in accordance with the magnitude of the present mark and the magnitude of the trailing space of input NRZI data to thus control the waveform of the write pulse, thereby minimizing jitter. Also, the waveform of the write pulse may be optimized in accordance with land/groove signals. Also, in the present invention, grouping may be performed differently for the respective zones, using grouping pointers.

A new adaptive writing method according to the present invention can be adopted to most high-density optical recording apparatuses using an adaptive writing pulse.

[Effect of the Invention]

As described above, the widths of the first and/or last pulses of a write pulse waveform are varied in accordance with the magnitude of the present mark of input NRZI data and the magnitude of the leading or trailing space, thereby minimizing jitter to enhance system reliability and performance. Also, the width of a write pulse is controlled by grouping the magnitude of the present mark and the magnitude of the leading or trailing spaces, thereby reducing the size of a hardware.

What is claimed is:

1. In a method for writing input data on an optical recording medium by a write pulse whose waveform is comprised of a first pulse, a last pulse and a multi-pulse train, an adaptive writing method comprising the steps of:

(a) controlling the waveform of the write pulse in accordance with the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces to generate an adaptive write pulse; and

(b) writing the input data by the adaptive write pulse on the optical recording medium.

2. The adaptive writing method according to claim 1, wherein the step (a) includes the step of generating an adaptive write pulse in which the rising edge of the first pulse is varied in accordance with the magnitude of the leading space and the magnitude of the present mark.

3. The adaptive writing method according to claim 1, wherein the step (a) includes the step of generating an adaptive write pulse in which the falling edge of the last pulse is varied in accordance with the magnitude of the present mark and the magnitude of the trailing space.

4. The adaptive writing method according to claim 1, wherein the step (a) includes the step of generating an adaptive write pulse in which the rising edge of the first pulse is varied in accordance with the magnitude of the leading space and the magnitude of the present mark, and the falling edge of the last pulse is varied in accordance with the magnitude of the present mark and the magnitude of the trailing space.

5. The adaptive writing method according to claim 1, wherein the step (a) includes the step of generating an adaptive write pulse in which the rising edge of the first pulse is shifted back and forth in accordance with the magnitude of the leading space and the magnitude of the present mark, and the falling edge of the last pulse is shifted back and forth in accordance with the magnitude of the present mark and the magnitude of the trailing space.

6. The adaptive writing method according to claim 5, wherein the light power for a predetermined channel is applied during the period corresponding to the shift of the rising edge of the first pulse and during the period corresponding to the shift of the falling edge of the last pulse.

7. The adaptive writing method according to claim 1, further comprising the step of:

(c) correcting the waveform of the adaptive write pulse in accordance with a land/groove signal indicating whether the input data is data of a land track or data of a groove track.

8. An adaptive writing method comprising the steps of:

(a) selecting one of grouping tables grouped by the magnitudes of mark and space of input data, using a grouping pointer;

(b) calculating the width of a write pulse using the data stored in the selected grouping table; and

(c) writing the input data using an adaptive write pulse generated responsive to the calculated width on an optical recording medium.

9. The adaptive writing method according to claim 8, wherein the grouping tables store width data of the first and/or last pulses of a write pulse waveform, by grouping the magnitude of the present mark of input data and the magnitudes of the leading and/or trailing spaces, into a short pulse group, a middle pulse group and a long pulse group.

10. The adaptive writing method according to claim 8, wherein the grouping tables store width data of the first and/or last pulses of a write pulse waveform, by grouping the magnitude of the present mark of input data and the magnitudes of the

leading and/or trailing spaces, into a short pulse group, a middle pulse group and a long pulse group, depending on whether the input data is in a land track or a groove track.

11. The adaptive writing method according to claim 8, wherein the grouping tables store width data of the first and/or last pulses of a write pulse waveform, by grouping the magnitude of the present mark and the magnitudes of the leading and/or trailing spaces, into a short pulse group, a middle pulse group and a long pulse group, for the respective zones on a recording medium.

12. The adaptive writing method according to claim 8, wherein the step (b) comprises the sub-steps of:

(b1) reading a shift value of the rising edge of the first pulse in accordance with a combination of the magnitude of the leading space and the magnitude of the present mark to calculate the width data of the first pulse; and

(b2) reading a shift value of the falling edge of the last pulse in accordance with a combination of the magnitude of the present mark and the magnitude of the trailing space to calculate the width data of the last pulse.

13. In a method for writing input data on an optical recording medium by a write pulse whose waveform is comprised of a first pulse, a last pulse and a multi-pulse train, for optimizing the light power of a light source, an adaptive writing method comprising the steps of:

(a) discriminating between the magnitudes of a present mark of input data and leading and/or trailing spaces;

(b) generating pulse width data for varying the widths of first and/or last pulses of the write pulse waveform in accordance with the magnitude of the present mark and the magnitudes of the leading and/or trailing spaces; and

(c) generating an adaptive write pulse in accordance with the pulse width data, converting the adaptive write pulse into a current signal in accordance with the driving

power levels for the respective channels for the adaptive write pulse to drive the light source.

14. The adaptive writing method according to claim 13, wherein the step (b) comprises the sub-steps of:

(b1) generating first pulse width data for shifting the rising edge of the first pulse back and forth in accordance with the magnitude of the leading space and the magnitude of the present mark; and

(b2) generating first pulse width data for shifting the falling edge of the last pulse back and forth in accordance with the magnitude of the present mark and the magnitude of the trailing space.

15. The adaptive writing method according to claim 14, wherein the light power for a predetermined channel is applied during the period corresponding to the shift of the rising edge of the first pulse and during the period corresponding to the shift of the falling edge of the last pulse.

16. The adaptive writing method according to claim 13, further comprising the step of:

(d) correcting the waveform of the adaptive write pulse in accordance with a land/groove signal indicating whether the input data is data of a land track or data of a groove track, wherein the input data is NRZI (Non-Return Zero Inversion) data.

17. In an apparatus for writing input data on an optical recording medium by a write pulse whose waveform is comprised of a first pulse, a last pulse and a multi-pulse train, an adaptive writing circuit comprising:

a discriminator for discriminating the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces;

a generator for controlling the waveform of the write pulse in accordance with the magnitude of the present mark of the input data and the magnitudes of the leading and/or trailing spaces to generate an adaptive write pulse; and

a driver for driving the light source by converting the adaptive write pulse into a current signal in accordance with driving power levels for the respective channels.

18. The adaptive writing circuit according to claim 17, wherein the generator includes a write waveform controller for generating pulse width data for varying the width of the first pulse in accordance with the magnitude of the leading space and the magnitude of the present mark and varying the width of the last pulse in accordance with the magnitude of the present mark and the magnitude of the leading space, and a write pulse generator for generating an adaptive write pulse in accordance with the pulse width data.

19. The adaptive writing circuit according to claim 18, wherein the write waveform controller is comprised of a memory in which width data of the first and/or last pulses of a write pulse waveform are stored, by grouping the magnitude of the present mark and the magnitudes of the leading and/or trailing spaces, into a short pulse group, a middle pulse group and a long pulse group.

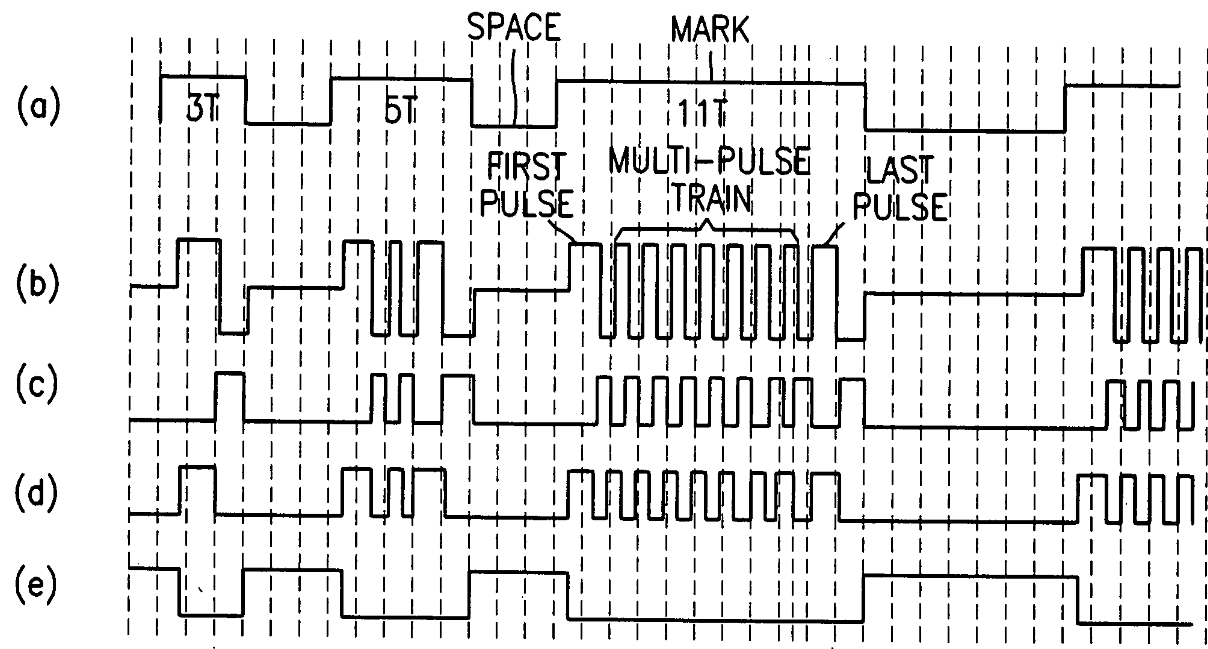
20. The adaptive writing circuit according to claim 19, further comprising a microcomputer for initializing the write waveform controller and controlling the pulse width data stored in the memory to be updated in accordance with write conditions.

21. The adaptive writing circuit according to claim 19, wherein the memory stores width data of the first and/or last pulses of a write pulse waveform depending on whether the input data is in a land track or a groove track.

22. The adaptive writing circuit according to claim 19, wherein the memory stores width data of the first and/or last pulses of a write pulse waveform for the respective zones on a recording medium.

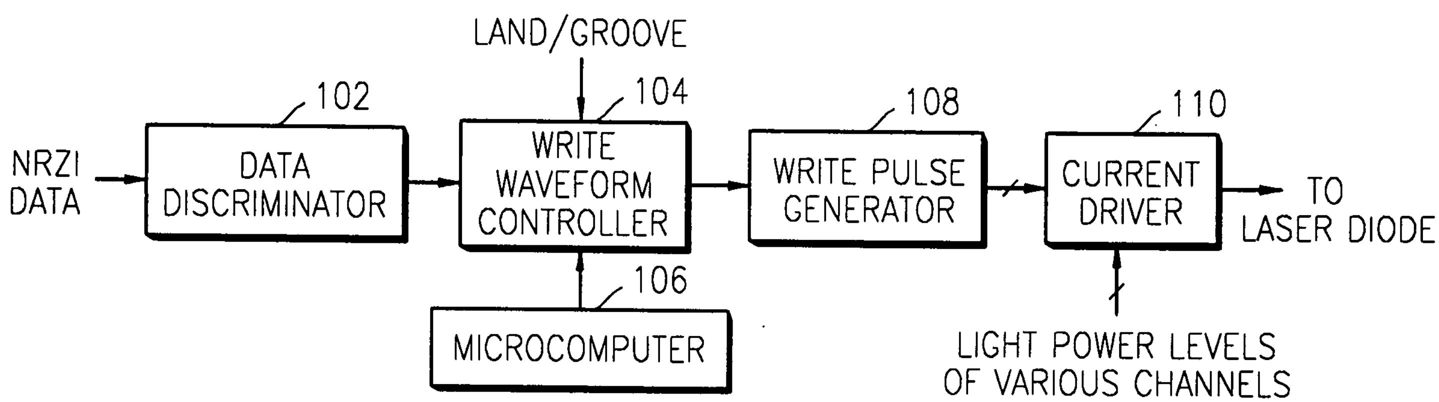
23. The adaptive writing circuit according to claim 19, wherein the light power for a predetermined channel is applied during the period corresponding to the shift of the rising edge of the first pulse and during the period corresponding to the shift of the falling edge of the last pulse.

FIG. 1



SPACE
MARK
(a)
3T
5T
11T
FIRST PULSE
MULTI-PULSE TRAIN
LAST PULSE
(b)
(c)
(d)
(e)

FIG. 2



LAND/GROOVE
NRZI DATA
102
DATA DISCRIMINATOR
104
WRITE WAVEFORM CONTROLLER
106
MICROCOMPUTER
108
WRITE PULSE GENERATOR
110
CURRENT DRIVER
TO LASER DIODE
LIGHT POWER LEVELS OF VARIOUS CHANNELS

FIG. 3

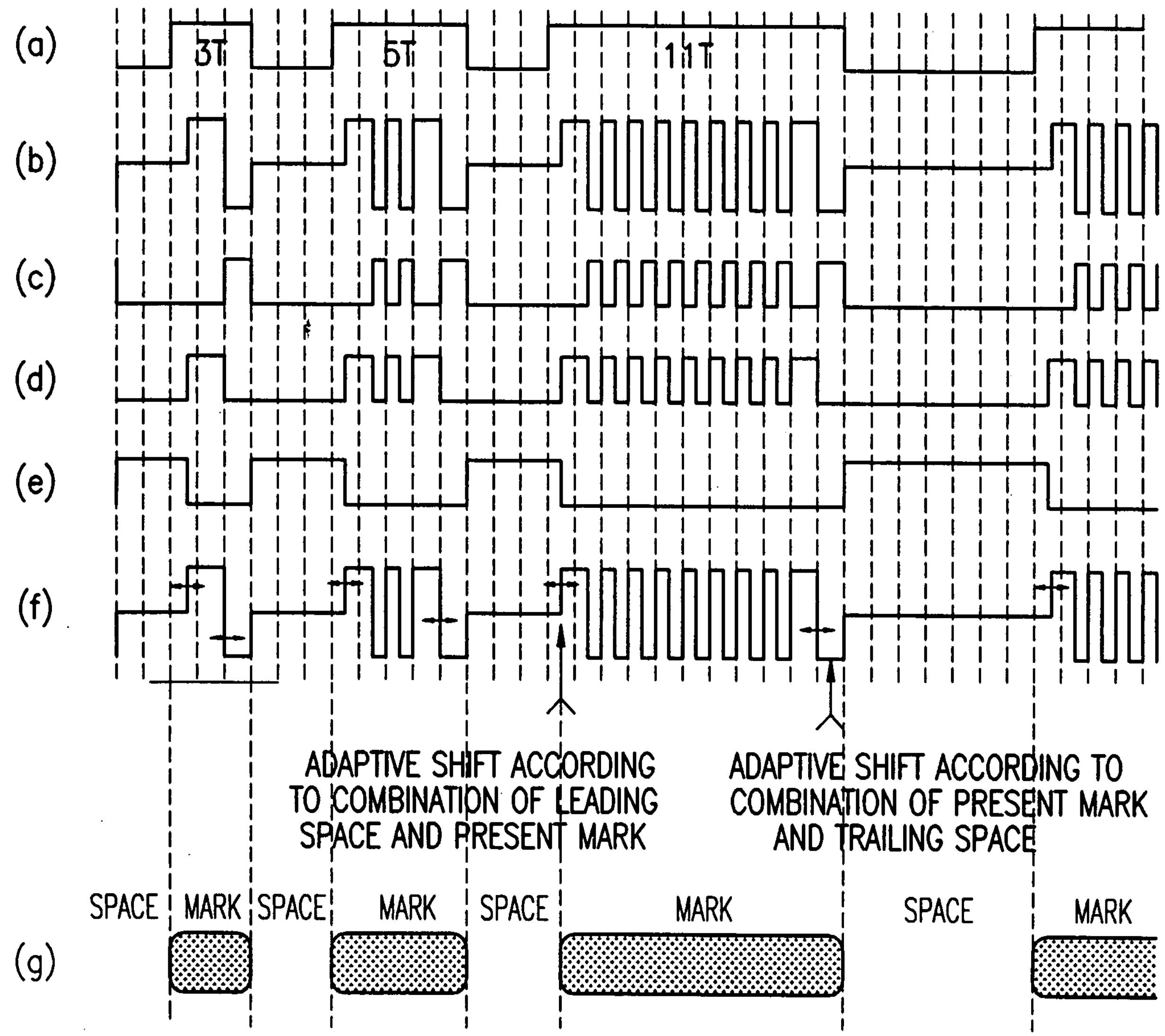

(a)
(b)
(c)
(d)
(e)
(f)
(g)
3T
5T
11T
ADAPTIVE SHIFT ACCORDING TO COMBINATION OF LEADING SPACE AND PRESENT MARK
ADAPTIVE SHIFT ACCORDING TO COMBINATION OF PRESENT MARK AND TRAILING SPACE
SPACE
MARK
SPACE
MARK
SPACE
MARK
SPACE
MARK

FIG. 4

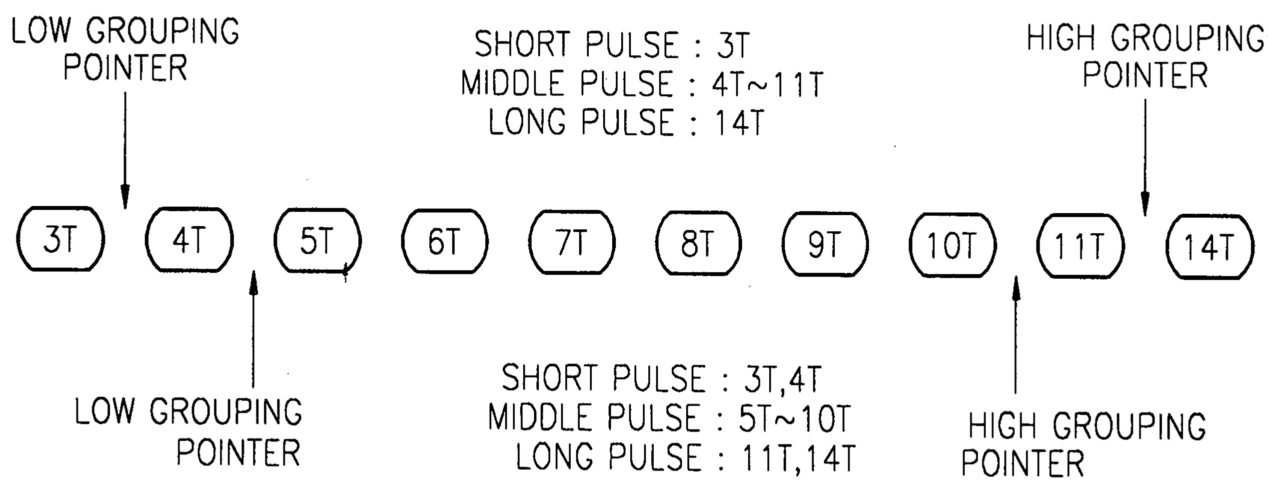

LOW GROUPING POINTER
SHORT PULSE : 3T
MIDDLE PULSE : 4T~11T
LONG PULSE : 14T
HIGH GROUPING POINTER
3T
4T
5T
6T
7T
8T
9T
10T
11T
14T
LOW GROUPING POINTER
SHORT PULSE : 3T,4T
MIDDLE PULSE : 5T~10T
LONG PULSE : 11T,14T
HIGH GROUPING POINTER

FIG. 5

LEADING PULSE SPACE	PRESENT MARK	TRAILING PULSE SPACE
SHORT PULSE	SHORT PULSE	SHORT PULSE
SHORT PULSE	SHORT PULSE	MIDDLE PULSE
SHORT PULSE	SHORT PULSE	LONG PULSE
SHORT PULSE	MIDDLE PULSE	SHORT PULSE
SHORT PULSE	MIDDLE PULSE	MIDDLE PULSE
SHORT PULSE	MIDDLE PULSE	LONG PULSE
SHORT PULSE	LONG PULSE	SHORT PULSE
SHORT PULSE	LONG PULSE	MIDDLE PULSE
SHORT PULSE	LONG PULSE	LONG PULSE
MIDDLE PULSE	SHORT PULSE	SHORT PULSE
MIDDLE PULSE	SHORT PULSE	MIDDLE PULSE
MIDDLE PULSE	SHORT PULSE	LONG PULSE
MIDDLE PULSE	MIDDLE PULSE	SHORT PULSE
MIDDLE PULSE	MIDDLE PULSE	MIDDLE PULSE
MIDDLE PULSE	MIDDLE PULSE	LONG PULSE
MIDDLE PULSE	LONG PULSE	SHORT PULSE
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MIDDLE PULSE	LONG PULSE	LONG PULSE
LONG PULSE	SHORT PULSE	SHORT PULSE
LONG PULSE	SHORT PULSE	MIDDLE PULSE
LONG PULSE	SHORT PULSE	LONG PULSE
LONG PULSE	MIDDLE PULSE	SHORT PULSE
LONG PULSE	MIDDLE PULSE	MIDDLE PULSE
LONG PULSE	MIDDLE PULSE	LONG PULSE
LONG PULSE	LONG PULSE	SHORT PULSE
LONG PULSE	LONG PULSE	MIDDLE PULSE
LONG PULSE	LONG PULSE	LONG PULSE

FIG. 6

LEADING PULSE SPACE	PRESENT MARK	SHIFT VALUE OF RISING EDGE OF FIRST PULSE(nS)
SHORT PULSE	SHORT PULSE	+1
SHORT PULSE	MIDDLE PULSE	−1
SHORT PULSE	LONG PULSE	−3
MIDDLE PULSE	SHORT PULSE	+2
MIDDLE PULSE	MIDDLE PULSE	0
MIDDLE PULSE	LONG PULSE	−2
LONG PULSE	SHORT PULSE	−3
LONG PULSE	MIDDLE PULSE	−1
LONG PULSE	LONG PULSE	0

FIG. 7

PRESENT MARK	TRAILING PULSE SPACE	SHIFT VALUE OF RSING EDGE OF LAST PULSE(nS)
SHORT PULSE	SHORT PULSE	+1
MIDDLE PULSE	SHORT PULSE	+2
LONG PULSE	SHORT PULSE	+4
SHORT PULSE	MIDDLE PULSE	−1
MIDDLE PULSE	MIDDLE PULSE	0
LONG PULSE	MIDDLE PULSE	+1
SHORT PULSE	LONG PULSE	−3
MIDDLE PULSE	LONG PULSE	−1
LONG PULSE	LONG PULSE	0

FIG. 8

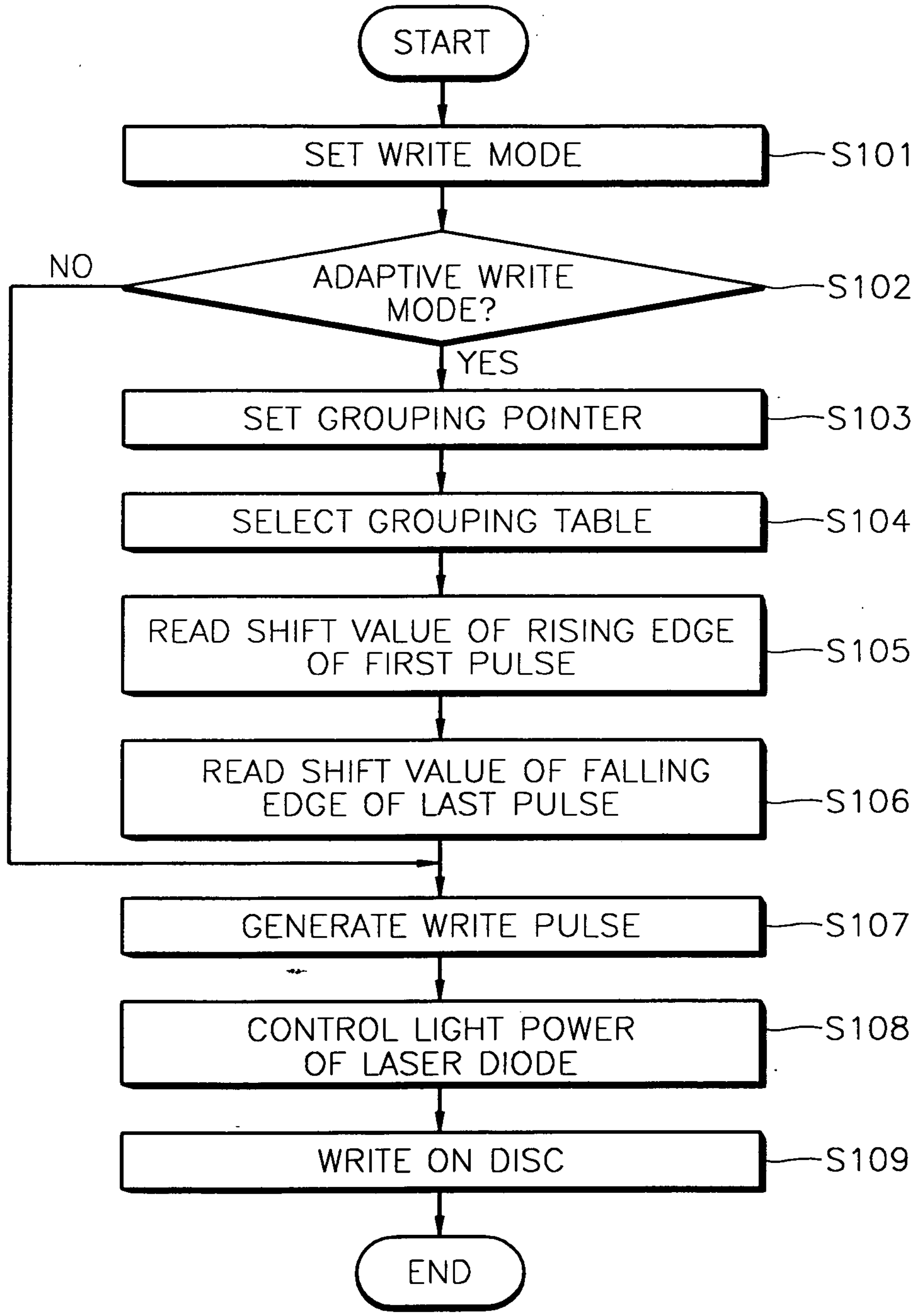
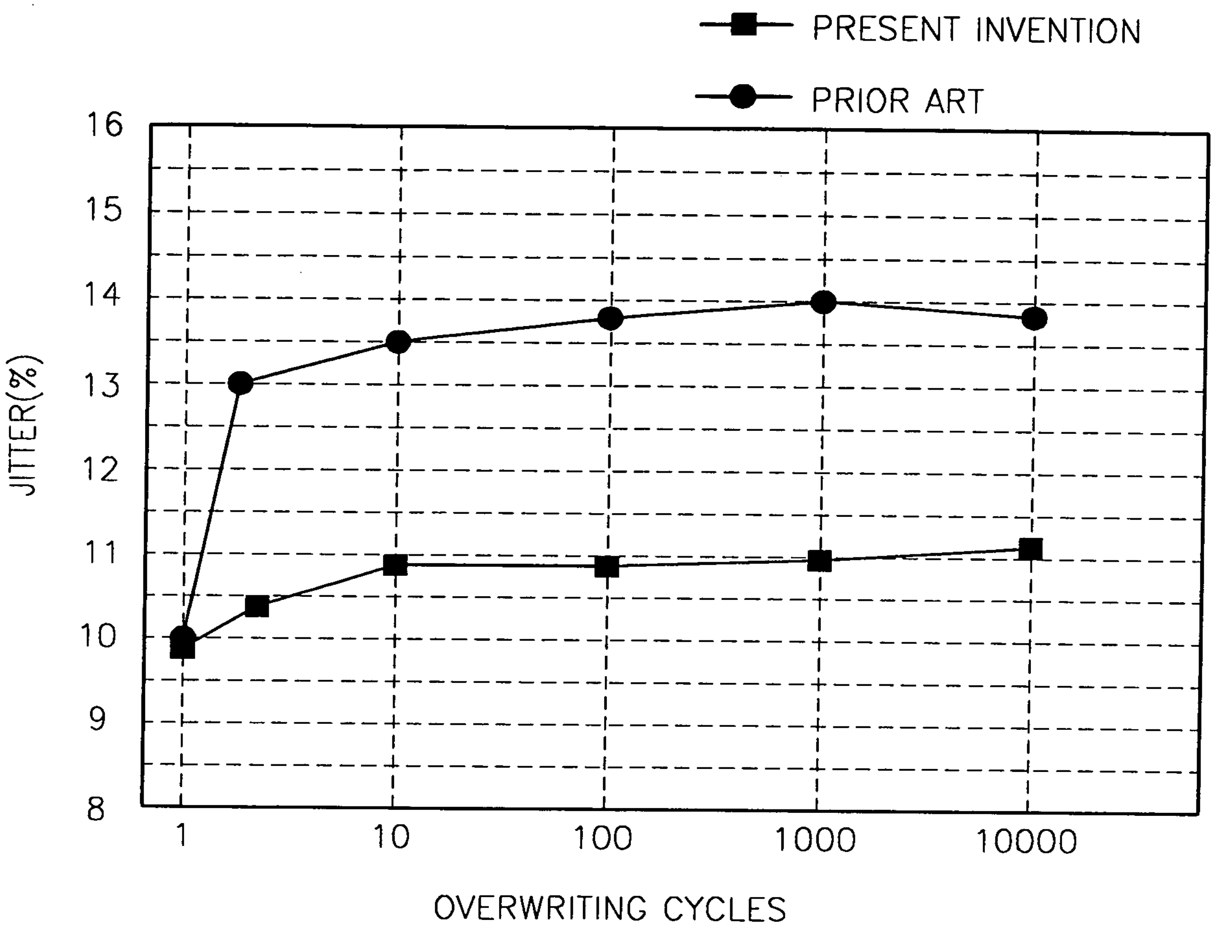

START
SET WRITE MODE
S101
ADAPTIVE WRITE MODE?
S102
NO
YES
SET GROUPING POINTER
S103
SELECT GROUPING TABLE
S104
READ SHIFT VALUE OF RISING EDGE OF FIRST PULSE
S105
READ SHIFT VALUE OF FALLING EDGE OF LAST PULSE
S106
GENERATE WRITE PULSE
S107
CONTROL LIGHT POWER OF LASER DIODE
S108
WRITE ON DISC
S109
END

FIG. 9


PRESENT INVENTION
PRIOR ART
16
15
14
13
12
11
10
9
8
JITTER(%)
1
10
100
1000
10000
OVERWRITING CYCLES